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Modeling of Multiconductor Shielded Microstrip Lines

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Abstract – **This paper presents a modeling of multiconductor transmission lines using COMSOL, a finite element package. We determined the capacitance coupling of the three-strip, six-strip, and eight-strip shielded microstrip lines. We compared our results with those obtained by other methods and found them to be close.**

Keywords – **Multiconductor Shielded microstrip line, Capacitance per unit length, Modelling and simulation.**

I. Introduction

Today, electromagnetic propagation on multiple parallel transmission lines has been a very attractive area in computational electromagnetics. Multiple parallel transmission lines have been successfully applied and used by designers in compact packaging, semiconductor device, high speed interconnecting buses, monolithic integrated circuits, and other applications.

Many authors have already calculated the multiconductor line capacitances using different approaches. Those approaches include analytical approach [1-2], the method of lines [3], finite element method [4-5], quasi-TEM spectral domain analysis [6], integral-equation computer-solution technique [7-9], conformal mapping technique [10], and the moment method [11].

In this paper, we consider systems of three-strip, six-strip, and eight-strip (multiconductor) shielded microstrip lines. Using COMSOL, a finite element package, we performed the simulation of these systems of microstrip lines.

II. Capacitance model

For coupled multiconductor microstrip lines, it is convenient to write as [12-13]:

$$Q_i = \sum_{j=1}^{m} C_{sij} V_j \quad (\text{i = 1, 2, ….., m}) \qquad (1)$$

where Q_i is the charge per unit length, V_j is the voltage of j th conductor with reference to the ground plane, C_{sij} is the short circuit capacitance between i th conductor and j th conductor. The short circuit capacitances can be obtained either from measurement or from numerical computation. From the short circuit capacitances, we obtain

$$C_{ii} = \sum_{j=1}^{m} C_{sij} \qquad (2)$$

where C_{ii} is the capacitance per unit length between the i th conductor and the ground plane. Also,

$$C_{ij} = -C_{sij}, \quad j \neq i \qquad (3)$$

where C_{ij} is the coupling capacitance per unit length between the i th conductor and j th conductor. The coupling capacitances are illustrated in Fig. 1.

For m-strip line, the per-unit-length capacitance matrix is given by

$$C = \begin{bmatrix} C_{11} & -C_{12} & \cdots & -C_{1m} \\ -C_{21} & C_{22} & \cdots & -C_{2m} \\ \vdots & \vdots & & \vdots \\ -C_{m1} & -C_{m2} & \cdots & C_{mm} \end{bmatrix} \qquad (4)$$

Also, we can determine the characteristic impedance matrix for m-strip line by

$$Z_o = \begin{bmatrix} Z_{11} & Z_{12} & \cdots & Z_{1m} \\ Z_{21} & C_{22} & \cdots & Z_{2m} \\ \vdots & \vdots & & \vdots \\ Z_{m1} & Z_{m2} & \cdots & Z_{mm} \end{bmatrix} \qquad (5)$$

where Z_o is the characteristic impedance per unit length.

III. Results and discussion

Using COMSOL for modeling and simulation of the lines involves taking the following steps:

1. Develop the geometry of the line, such as shown in Fig. 2.
2. We take the difference between the conductor and dielectric material
3. We select the relative permittivity as 1 for the difference in step 2.
4. We add a dielectric region under the inner conductors with specified relative permittivity.
5. For the boundary, we select the outer conductor as ground and the inner conductors as ports.
6. We generate the finite element mesh, and then we solve the model.
7. As postprocessing, we select Point Evaluation and choose capacitance elements to find the coupling capacitance per unit length of the line.

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These steps were taken for the following three cases.

A.Three-strip line

Figure 2 shows the cross section for three-strip line with the following parameters:

a = width of the outer conductor = 13 mm
b = height of the free space region (air) = 4 mm
h = height of the dielectric region = 2 mm
w = width of each inner strip = 2 mm
t = thickness of each inner strip = 0.01 mm
D = distance between the outer conductor and the first strip = 2.5 mm
s = distance between two consecutive strips = 1 mm

Figure 3 shows the finite element mesh, while Fig. 4 illustrates the potential distribution along line y = h. Table I shows the finite element results for the three-strip line. Unfortunately, we could not find any work in the literature to compare our results.

TABLE I
CAPACITANCE VALUES (IN p F / m) FOR THREE –STRIP SHIELDED MICROSTRIP LINE

Methods	C_{11}	C_{21}	C_{31}
COMSOL[16]	163.956	-27.505	-0.4301

B. Six-strip line

Figure 5 shows the cross section for six-strip line with the following parameters:

a = width of the outer conductor = 15 mm
b = height of the free space region (air) = 2 mm
h = height of the dielectric region = 8 mm
w = width of each inner strip = 1 mm
t = thickness of each inner strip = 0.01 mm
D = distance between the outer conductor and the first strip = 2 mm
s = distance between two consecutive strips = 1 mm

Figure 6 shows the finite element mesh, while Fig. 7 depicts the potential distribution along line y = h. The capacitance values for six-strip shielded microstrip line are compared with other methods as shown in Table II, where "iterative" refers to an iterative method [14] and ABC refers to the asymptotic boundary condition [15]. It is evident from the table that the finite element methods based on [4] and [16] closely agree. The finite element methods seem to be more accurate than the iterative and ABC techniques.

C. Eight-strip line

Figure 8 shows the cross section for eight-strip line with the following parameters:

a = width of the outer conductor = 175 mm
b = height of the free space region (air) = 100 mm
h = height of the dielectric region = 16 mm
w = width of each inner strip = 1 mm
t = thickness of each inner strip = 0.01 mm
D = distance between the outer conductor and the first strip = 80 mm
s = distance between two consecutive strips = 1 mm

Figure 9 shows the finite element mesh, while Fig. 10 depicts the potential distribution along line y = 20mm. The capacitance values for eight-strip shielded microstrip line are compared with other methods as shown in Table III, where other authors used analytic approach [17] and Fourier series expansion [18]. It is evident from the table that the results from finite element method (COMSOL) closely agree with the analytic approach.

IV. CONCLUSION

In this paper, we have presented the modeling of three-strip, six-strip, and eight-strip (multiconductor) shielded microstrip lines. The results obtained using COMSOL for the coupling capacitance per unit length agree well those found in the literature.

REFERENCES

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[1] D. Homentcovshi et al., "An analytic solution of the coupled stripline-like microstrip line problem," *IEEE Transactions on Microwave Theory and Techniques*, vol. 36, no. 6, June 1988, pp. 1002-1007.
[2] D. Homentcovshi, G. Ghione, and C. Naldi, "Analytic determination of the capacitance matrix of planar or cylindrical multiconductor lines on multilayered substrates," *IEEE Transactions on Microwave Theory and Techniques*, vol. 43, no. 2, Feb. 1995, pp. 363-373.
[3] M. Davidovitz, "Calculation of multiconductor microstrip line capacitances using the semidiscrete finite element method," *IEEE Microwave and Guided Wave Letters*, vol. 1, no. 1, Jan. 1991, pp. 5-7.
[4] A. Khebir, A. B. Kouki, and R. Mittra, "High order asymptotic boundary condition for the finite element modeling of two-dimensional transmission line structures," *IEEE Transactions on Microwave Theory and Techniques*, vol. 38, no. 10, Oct. 1990, pp. 1433-1438.
[5] Z. Pantic and R. Mittra, "Quasi-TEM analysis of microwave transmission lines by the finite-element method," *IEEE Transactions on Microwave Theory and Techniques*, vol. 34, no. 11, Nov. 1986, pp. 1096-1103.
[6] E. Drake, F. Medina, and M. Horno, "Improved quasi-TEM spectral domain analysis of boxed coplanar multiconductor microstrip lines," *IEEE Transactions on Microwave Theory and Techniques*, vol. 41, no. 2, Feb. 1993, pp. 260-267.
[7] A. E. Ruehli and P. A. Brennan, "Efficient capacitances for three-dimensional multiconductor systems," *IEEE Transactions on Microwave Theory and Techniques*, vol. 21, no. 2, Feb. 1973, pp. 76-82.

[8] W. T. Weeks, "Calculation of coefficients of capacitance of multiconductor transmission lines in the presence of a dielectric interface," *IEEE Transactions on Microwave Theory and Techniques*, vol. 18, no. 1, Feb. 1970, pp. 35-43.

[9] W. Delbare and D. De Zutter, "Space-domain Green's function approach to the capacitance calculation of multiconductor lines in multilayered dielectrics with improved surface charge modeling, *IEEE Transactions on Microwave Theory and Techniques*, vol. 37, no. 10, Oct. 1989, pp. 1562-1568.

[10] C. Wan, "Analytically and accurately determined quasi-static parameters of coupled microstrip lines," *IEEE Transactions on Microwave Theory and Techniques*, vol. 44, no. 1, Jan. 1996, pp. 75-80.

[11] C. Wei et al, "Multiconductor transmission lines in multilayered dielectric media," *IEEE Transactions on Microwave Theory and Techniques*, vol. 32, no. 4, April 1984, pp. 439-450.

[12] M. S. Lin, "Measured capacitance coefficients of multiconductor microstrip lines with small dimensions," *IEEE Transactions on Microwave Theory and Techniques*, vol. 13, no. 4, Dec. 1990, pp. 1050-1054.

[13] F. Y. Chang, "Transient analysis of lossless coupled transmission lines in a nonhomogeneous dielectric media," *IEEE Trans. Microwave Theory Tech.*, vol 18, no 9, pp. 616-626, Aug. 1970.

[14] P. N. Harms, C. H. Chan, and R. Mittra, "Modeling of planar transmission line structures for digital circuit applications," Arch. Eleck. Ubertragung., vol. 43, 1989, pp. 245-250.

[15] A. Kherbir, A. B. Kouki, and R. Mittra, "Absorbing boundary condition for quasi-TEM analysis of microwave transmission lines via the finite element method," *J. Electromagn. Waves and Appl.*, vol. 4, no. 2, 1990.

[16] www.comsol.com

[17] D. Homentcovschi, G. Ghione, C. Naldi, and R. Oprea," Analytic determination of the capacitance matrix of planar or cylindrical multiconductor lines," *IEEE Trans. Microwave Theory Tech.*, pp. 363-373, Feb. 1995.

[18] M. K. Amirhosseini," Determination of capacitance and conductance matrices of lossy shielded coupled microstrip transmission lines," *Progress In Electromagnetics Research*, PIER 50, pp. 267-278, 2005.

TABLE II
CAPACITANCE VALUES (IN p F / m) FOR SIX –STRIP SHIELDED MICROSTRIP LINE

Methods	C_{11}	C_{21}	C_{31}	C_{41}	C_{51}	C_{61}
Iterative [14]	66.8	-27.9	-5.49	-2.08	-0.999	-0.704
Finite Element [4]	84.8	-26.4	-3.71	-1.17	-0.456	-0.812
ABC [15]	68.6	-31.5	-6.00	-2.25	-0.792	-0.602
COMSOL [16]	80.4	-23.9	-3.61	-1.15	-0.451	-0.180

TABLE III
CAPACITANCE VALUES (IN p F / m) FOR EIGHT –STRIP SHIELDED MICROSTRIP LINE

Method	C_{11}	C_{21}	C_{31}	C_{41}	C_{51}	C_{61}	C_{71}	C_{81}
Analytic [17]	127.776	-58.446	-13.024	-5.721	-3.104	-1.892	-1.282	-1.211
Fourier series [18]	126.149	-57.066	-12.927	-5.684	-3.086	-1.875	-1.264	-1.185
COMSOL [16]	128.204	-58.759	-13.064	-5.739	-3.1206	-1.902	-1.290	-1.226

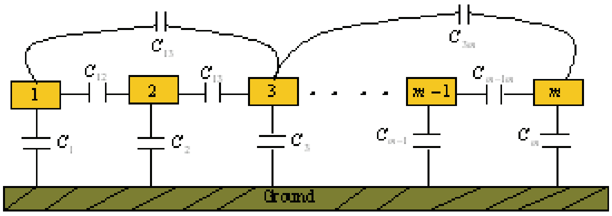

Fig. 1 The per-unit length capacitances of a general m -conductor transmission line.

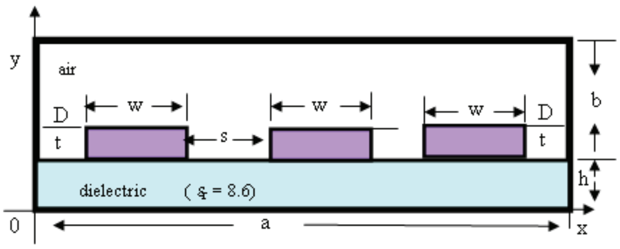

Fig. 2 Cross-section of the three-strip transmission line.

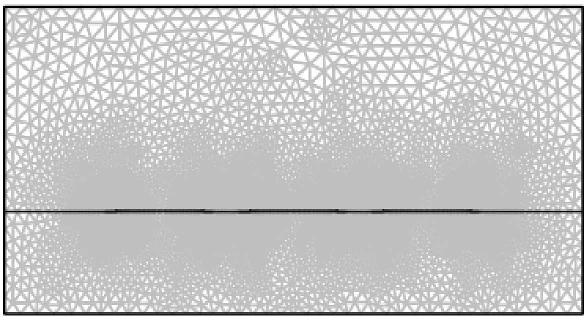

Fig. 3 Mesh for the three-strip transmission line.

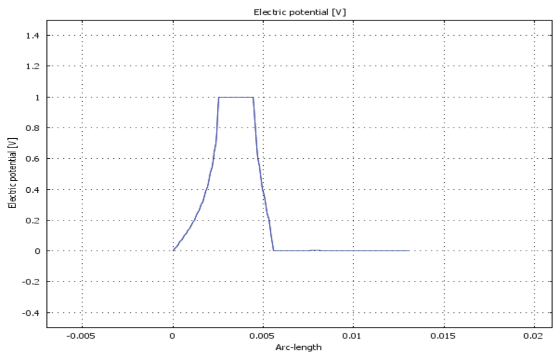

Fig. 4 Potential distribution along the air-dielectric interface (y = h) for the three-strip transmission line.

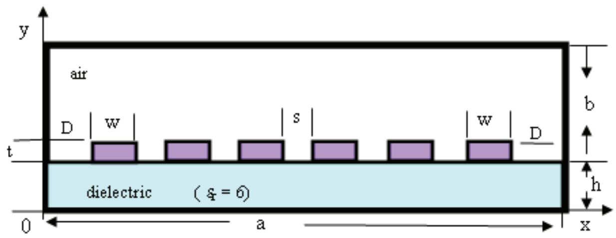

Fig. 5 Cross-section of the six-strip transmission line.

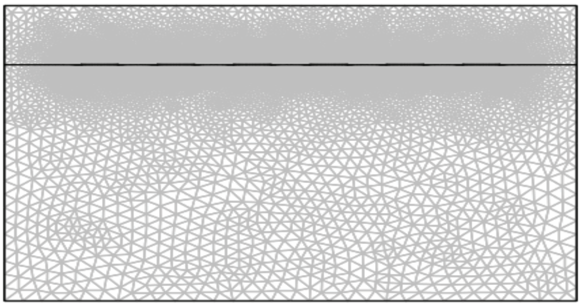

Fig. 6 Mesh for the six-strip transmission line.

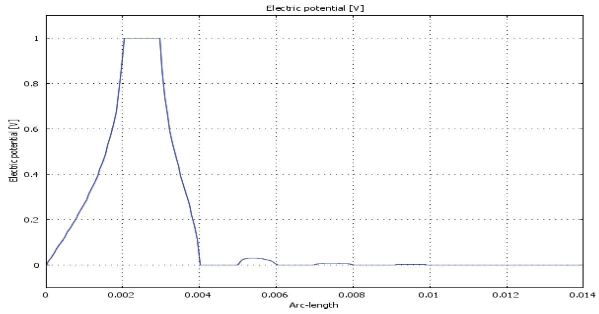

Fig. 7 Potential distribution along the air-dielectric interface (y = h) for the six-strip transmission line.

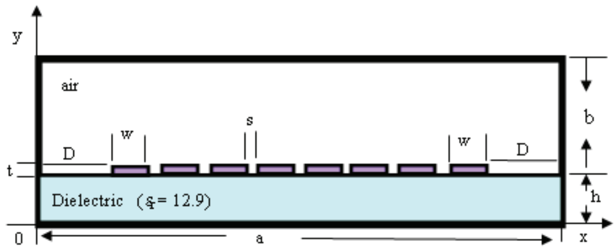

Fig. 8 Cross-section of the eight-strip transmission line.

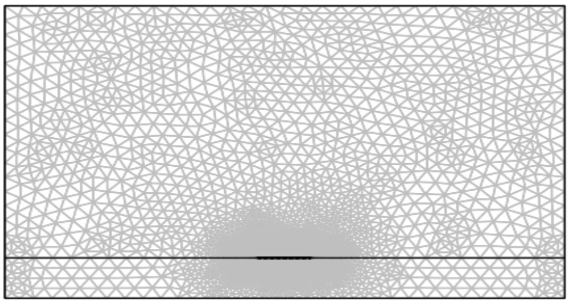

Fig. 9 Mesh for the eight-strip transmission line.

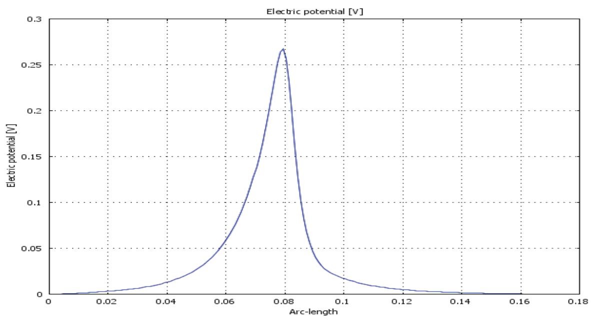

Fig. 10 Potential distribution along the air-dielectric interface (y = 20 mm) for the eight-strip transmission line.